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Potential of U.S. Marine and Offshore Wind Energy to Power Marine Carbon Dioxide Removal

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Abstract

The goal of this project was to provide a preliminary feasibility assessment of powering different marine carbon dioxide removal (mCDR), carbon capture (mCC), and carbon sequestration (mCS) strategies with marine energy. The investigation focused on methods with clear power requirements at sea beyond monitoring, such as artificial upwelling (AU), deep ocean storage, electrochemical (eChem) mCDR and mCC, offshore microalgae cultivation, and seaweed farming and sinking (see Figure 1). The project found that eChem mCDR powered by marine energy and offshore wind energy available in the United States could meet global CDR scales needed by 2040 and 2050 to limit warming to 1.5ºC by 2100, and marine energy alone could greatly contribute to reaching scales needed by 2040. Note that this preliminary estimate assumes that it is possible to harvest all the marine and offshore wind resources available in the United States with existing technology options. Though the biological methods were limited in scale, they still hold promise in developing carbon-negative fuels and products, which can reduce emissions in the short term.

Methods

This study was split into two parts: (1) the viability of the mCDR, mCC, and mCS methods in general and (2) their high-level compatibility with marine and offshore wind energy. The viability of the methods was assessed by determining their energy requirements, location needs, scalabilities, cost, technology readiness levels, and environmental impacts via a literature review and informed estimates based on information from literature, which largely involved unit conversions (see the report cited in this poster for more details). The determined longevity of CO_2 storage, scalabilities, and energy needs are detailed in Figure 2 along with thresholds based on existing onshore CDR technologies. The compatibility of the methods with offshore energy involved estimating possible scales that could be achieved using the marine and offshore wind energy available in the United States. The energy and location requirements determined in the literature review as well as the resources of marine and offshore wind energy that could be harvested using existing technologies at these locations were used to determine the scales, which were limited by the maximum possible scales anticipated from the literature (see Figure 3).

Forms of mCDR, mCC, & mCS

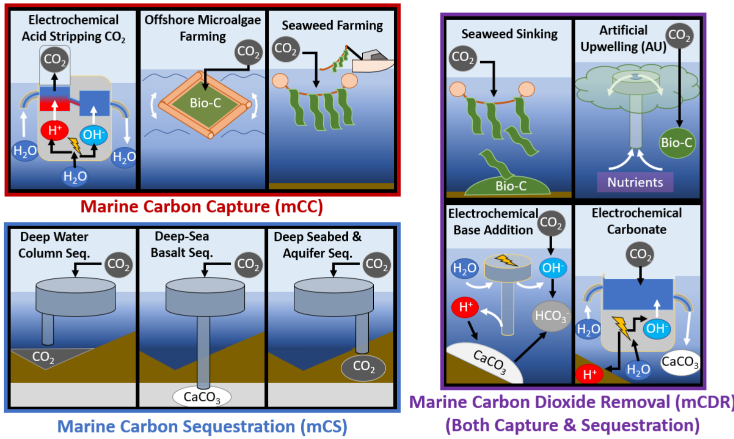

Figure 1: Simplified graphics of the methods investigated in this study grouped by whether they are forms of mCC, mCS, or mCDR.

Discussion

The goal of this project was to better understand the feasibility of using U.S. marine energy to power mCDR, mCC, and mCS strategies to reach scales that could mitigate climate change. The most promising mCDR, mCC, and mCS methods were those with potential scales above 1 $GtCO_2$/yr; energy needs below the upper quartile of those from onshore CDR, CC, and CS methods; and CO_2 storage times of 1,000 years for the mCDR and mCS methods. By these standards, the most promising mCDR methods were eChem base addition and carbonate formation; the most promising mCC method was eChem acid stripping CO_2; and the most promising mCS methods were deep-sea basalt and seabed sequestration. Aquifer sequestration is also promising, despite not meeting longevity requirements, because it is already being done in pilot projects at megaton scales, meaning that it has a higher technology readiness level and could be a good near-term partner for offshore renewable energy developers interested in using their technologies to power mCS to sequester CO_2 captured by eChem acid stripping CO_2 or other CC methods.

eChem mCDR methods (including eChem acid stripping combined with deep-sea aquifer sequestration) could use **U.S. offshore marine and wind energy** resources (that can be harvested by existing technologies) **to remove 10 $GtCO_2$/yr**, which could be used to **reach global removal targets needed by 2050** and assist in reaching those needed by 2100 to **limit warming to 1.5ºC by 2100** (see Figure 3). Marine energy alone could still be used to reach 1 $GtCO_2$/yr CDR scales with the eChem mCDR methods, which is still a significant step toward global removal targets (see Figure 3). The results highlight the potential global impacts of combining these technologies. This preliminary measure of compatibility will need to be verified with future studies that examine how specific technologies can be integrated with one another.

Despite the biological mCDR, mCC, and mCS methods not reaching all the performance thresholds set in this study, they still have their own benefits. Seaweed and microalgae farming can be used to make carbon-neutral biofuels and food, among other products, AU can support aquaculture, and seaweed sinking could be used in regions such as the Caribbean where a seaweed bloom is causing environmental, health, and financial strife.

Results

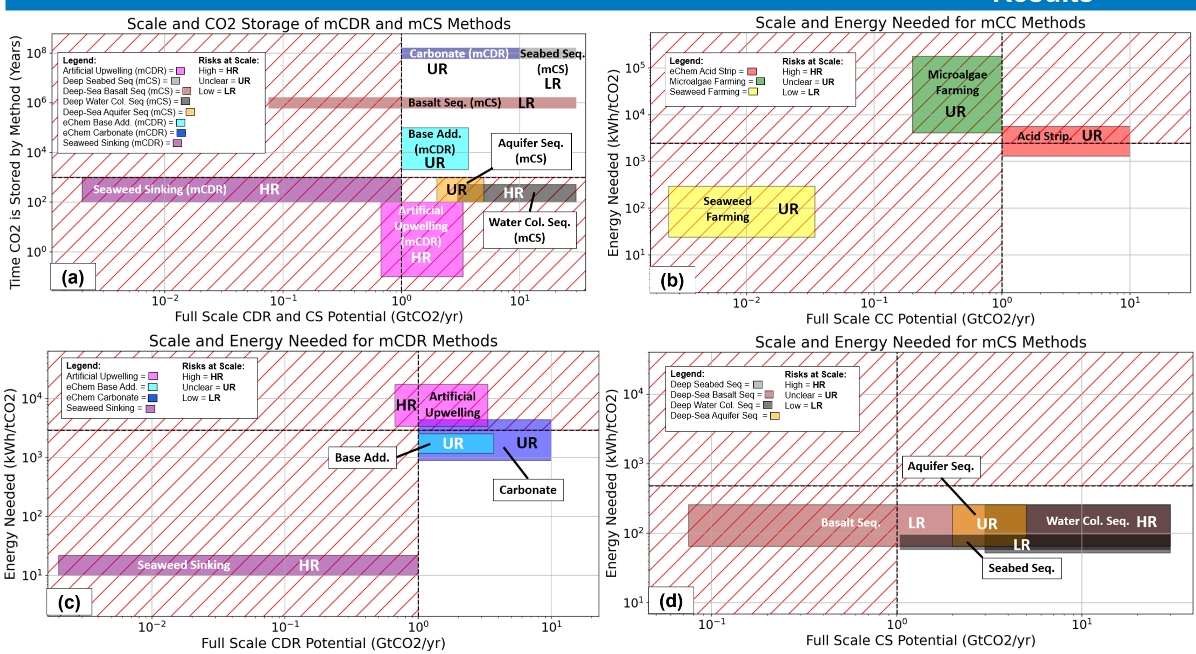

Figure 2: Scale vs. CO_2 storage for mCDR and mCS methods (**a**), and scale vs. energy needed per ton of CO_2 for mCC (**b**), mCDR (**c**), and mCS (**d**).

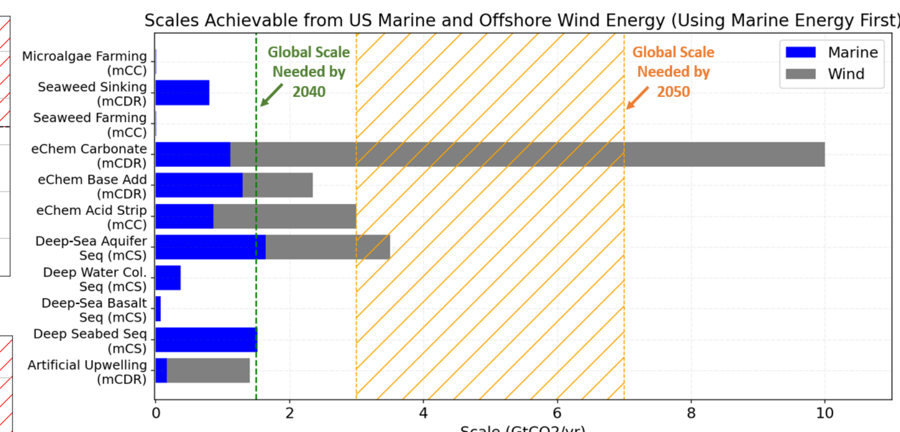

Figure 3: Theoretically achievable scales of mCDR, mCC, and mCS using the marine energy available in their appropriate U.S. locations followed by using offshore wind energy. Global scales needed to limit warming to 1.5ºC by 2100 also shown.

Technical Report Publication Citation

Niffenegger, James Salvador, David Greene, Robert Thresher, and Michael Lawson. 2023. *Mission Analysis for Marine Renewable Energy To Provide Power for Marine Carbon Dioxide Removal*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5700-87165. https://www.nrel.gov/docs/fy23osti/87165.pdf.

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Water Power Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.

AGU23
San Francisco, CA
11-15 December 2023
NREL/PO-5700-88155